

Long (J. H.)

[REPRINTED FROM THE JOURNAL OF ANALYTICAL CHEMISTRY,
VOL. IV, PART 1. JANUARY, 1890.]

ILLUSTRATIONS

OF

Sewage Decomposition in Streams.

BY J. H. LONG.



During the last four years I have had occasion to carry out a lengthy investigation on the question of pollution of streams in Illinois, and in the progress of the work have observed certain

points which I consider of interest to chemists dealing with analytical problems of similar nature.

This work was undertaken by authority of the State Board of Health, and since its beginning I have examined nearly 1000 samples. The results reached in a preliminary examination were presented to the Board in 1887. A few of them were explained in a paper in the *American Chemical Journal*, Vol. X, No. 1, while the methods employed and tabulated results of the whole will appear in a future annual report of the Board.

The largest part of the work consisted in a study of the Illinois river from its sources to its mouth, and it is only with this part of the subject that I have to deal here.

At all seasons of the year the upper Illinois river receives a good part of its water from Lake Michigan through a canal flowing southwest from Chicago to Joliet, when a union with a small stream known as the Des Plaines river is made. A few miles further toward the southwest these waters are joined by those from the Kankakee and Du Page, thus forming the Illinois proper. The watershed separating the basin of Lake Michigan from that of the Mississippi is very low, and is but a few miles from the lake. The canal referred to is fed by pumps, the water being drawn through the city and discharged by these pumps toward the west at the rate of 50,000 cubic feet per minute. The water in going through the city receives about three-fourths of its sewage, and in the canal flows undiluted to Joliet, a distance of 33 miles.

It will be seen, therefore, that we have here a most interesting problem. We have given a stream, highly contaminated at its source, and are able to follow and measure changes in the amount of contamination for many miles. In my first series of experiments, completed during the summer of 1886, very curious and important results were obtained. That season was unusually warm and dry, the rainfall in the part of the state under consideration being the lowest recorded in 15 years, and it was therefore possible to measure changes in the flowing river water, undisturbed by dilution of rain.

In the tests of that season, the determinations made were free and albuminoid ammonia and oxygen consumption by the

Kubel method. The following mean results were obtained, expressed in parts per 1,000,000.

	Free Ammonia.	Albuminoid Ammonia.	Oxygen Consumed.
Bridgeport	17.44	1.195	20.58
Lockport, 29 miles	10.23	.669	11.30
Joliet, 33 "	6.93	.408	7.79
Ottawa, 81 "	0.382	.237	5.57
Peoria, 159 "	0.035	.187	4.85

Between Bridgeport and Joliet the dilution was practically zero during the whole season. Between Joliet and Ottawa the Illinois receives the waters of the Kankakee, Du Page and Fox, so that at the last named place it was estimated that the canal water was reduced to 43 per cent. of the whole. But as a part of the diluting water came from a marshy region, it was by no means free from organic matter. Besides, some town drainage entered the stream between the two places. It is, therefore, probable, that a reduction in organic matter took place between these points. The proportion of canal water, in the whole, was but slightly changed between Ottawa and Peoria, while some drainage entered at the town of LaSalle. We can trace, therefore, a very remarkable decrease in organic matter between the contaminated source at Bridgeport and the city of Peoria. From a study of all the facts bearing on the case, I have held that this change was due chiefly to oxidation (using this term in the broad sense to include changes brought about by microorganisms) rather than to sedimentation.

During the following winter these mean results were obtained, expressed in parts per 1,000,000 :

	Free Ammonia.	Albuminoid Ammonia.	Oxygen Consumed.
Bridgeport	9.7	3.7	22.4
Joliet	6.5	2.2	11.3
Ottawa.	4.7	.75	9.0
Peoria	1.7	.43	6.45

In this table the increased amount of albuminoid ammonia with smaller amount of free ammonia at Bridgeport is apparent, and is, of course, due to the fact that decomposition is slower at a low temperature, and hence the sewage reached the pumps in a less advanced stage of oxidation. The large amount of albumi-

noid ammonia at Joliet is worthy of note at a time when sedimentation could accomplish the best results. The very slow decrease in free ammonia must also be noticed.

As intimated above, these tests may be considered as preliminary to a more complete investigation begun May 1st, 1888, and concluded in March, 1889. In this investigation water was collected once a week at the following places between the source of supply at Chicago and the Mississippi river: Bridgeport, Lockport, Joliet, Morris, Ottawa, LaSalle, Henry, Peoria, Pekin, Copperas Creek, Havana, Pearl, Beardstown and Grafton, the last being at the mouth of the Illinois river. Parallel tests were also made of the water supplied by the various tributaries of the Illinois to determine the nature of the dilution. In this investigation, in addition to free and albuminoid ammonia and oxygen consumption, total solids, suspended matter, nitrates, chlorides, and hardness were determined. In the following table only those data important for the present purpose are given and for places where water was regularly collected. During the early part of the season the rainfall throughout Illinois was heavy, in consequence of which the streams were full at times, adding much to the dilution of the main river.

The amount of this dilution can be roughly estimated from the chlorine determinations along the main stream and in the tributaries.

Mean Results of Analyses. May to October, 1888, inclusive.

IN PARTS PER MILLION.

Places.	Nitrogen in Nitrates and Nitrites.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	Oxygen Consumed.
Bridgeport	.000	46.811	12.253	2.558	23.113
Lockport	.000	46.120	10.882	1.990	16.230
Joliet	.000	43.658	8.932	1.681	14.301
Morris	.380	32.149	4.107	.707	10.920
LaSalle	1.037	19.717	.636	.526	8.558
Henry	.683	17.660	.467	.481	8.657
Peoria	.8915	12.358	.210	.522	9.769
Pekin	.795	16.152	.645	.650	9.410
Havana	.731	11.583	.342	.430	8.142
Beardstown	.62	7.524	.202	.380	7.354
Grafton	.582	9.205	.095	.483	7.300

Mean Results of Analyses. January to March, 1889, inclusive.

IN PARTS PER MILLION.

Places.	Nitrogen in Nitrates and Nitrites.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	Oxygen Consumed.
Bridgeport	.000	62.934	8.925	2.806	26.502
Lockport	.000	56.083	8.149	2.489	22.820
Joliet	.000	57.717	8.488	2.666	21.717
Morris	.000	28.748	47.16	1.587	10.696
LaSalle	.942	13.105	1.456	.637	8.582
Henry	.962	11.691	1.059	.404	8.626
Peoria	.510	12.860	1.637	.549	9.611
Pekin	1.259	11.792	1.591	1.015	13.358
Havana	.414	9.277	1.078	.585	9.234
Beardstown	.966	6.933	.762	.357	5.505
Grafton	.087	7.523	.875	.722	9.818

In explanation of some of the peculiarities of the above tables, it must be stated that while the rainfall during 1888 was much heavier than during 1886, the mean temperature was in a marked degree lower. The winter of 1888-'89 was, however, much milder than that of 1886-'87.

In comparing the summer tests of 1886 with those of 1888, we notice that at Bridgeport in the first named year the free ammonia was much higher and the albuminoid ammonia much lower than during the second season. It is also clear that the rate of change in these products between Bridgeport and Joliet is different for the two seasons. I think this can be largely looked upon as an effect of temperature, as dilution, contamination and agitation of water were practically the same within these limits through the two seasons. During the hot summer of 1886 much greater decomposition must have taken place in the Chicago sewers themselves than during the cooler one of 1888, so that in the first case the diluted sewage reached the pumps in a more advanced stage of oxidation than in the latter.

One would expect to find, under these circumstances, less free ammonia and more albuminoid than in a season when the oxidation conditions had been more favorable.

To follow the change in the sewage after it leaves Chicago in its flow toward the Mississippi, we must consider the character of the diluting water from the tributaries. The mean results ob-

tained by analysis of these waters are given here, in parts per million, as before.

	Nitrogen in Nitrates and Nitrites.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	Oxygen Consumed.
DuPage River, enters above Morris	.307	5.786	.417	.346	4.743
Kankakee River, en- ters above Morris .	.094	1.015	.114	.585	12.661
Fox River, at Ottawa, above LaSalle . . .	.027	4.974	.278	.463	7.066
Big Vermillion Riv., at LaSalle, ab. Henry	3.348	5.461	.129	.341	6.914
Sangamon River, above Beardstown .	.755	3.609	.053	.285	5.480

The flow from the DuPage is very small during the summer and its effect on the Illinois can be left out of consideration.

The Kankakee, draining a marshy country, has a steady flow throughout the summer and forms about 20 per cent. of the Illinois water at Morris. Its character is shown by low chlorine and nitrates and high albuminoid ammonia and oxygen consumption. Between Morris and LaSalle the Fox enters and dilutes the Illinois largely, as indicated by the decrease in chlorine. The dilution by the Big Vermillion is not large. The high nitrates here are worthy of interest. The city of Streator and several coal mines drain into the stream. Below Peoria the tributaries of importance are the Sangamon and Spoon. I have no data for the latter, but the results for the Sangamon are given above. Perhaps 30 per cent. of the flow at Beardstown comes from these two streams.

Aided by these data, we can now consider the main river. Between Bridgeport and Lockport, a distance of 29 miles, there is during the summer an evident disappearance of organic matter, as shown by change in the free and albuminoid ammonia and oxygen consumption. But during the winter the change is in a marked degree less. This is especially apparent if we notice that the chlorine tests during the winter show some dilution between the two places. From Lockport to Joliet the distance is four miles, but on its way the water passes through four locks and over two dams to point of collection. It is thus thoroughly agitated and aerated. During the summer the tests show a decrease in organic matter, but the winter examinations indicate, apparently, an increase,

as shown by albuminoid ammonia. A slight increase in free ammonia is also found. These observations are of practical importance. They show, first, that at Lockport the decomposing matter was not yet in condition to respond most perfectly to the albuminoid ammonia test, and also that the free ammonia gradually produced had accumulated rather than decreased by fermentation. Dilute solution of white of egg undergoing putrefaction yields its largest amount of albuminoid ammonia at the start, as shown by experiments carried out in my laboratory by Mr. Powers. (See Oct. 1889, number of this Journal.) But it is conceivable that solids in suspension, or other nitrogenous matters more stable than white of egg, would yield their largest amount of albuminoid only after preliminary disintegration.

Between Joliet and Morris the distance is 22 miles, and on the way there is a dilution of about 20 per cent. by water in which the numbers for albuminoid ammonia and oxygen consumption are high. A part of the drainage of Joliet enters here besides. Giving these points due weight, it will be seen that there is a large reduction of organic matter in this part of the stream during the summer. This is not chiefly due to sedimentation. It has been shown by engineers in charge of surveys along the Illinois river, that owing to sufficiently high velocity of the water, sedimentation does not take place here. During the winter the relative dilution from the Kankakee was much greater, about half the water at Morris coming from the last named stream. When the character of the diluting water is remembered, it is plain that the nitrogenous matter has suffered no change between the two places. In the 37 miles between Morris and LaSalle there is a great decrease in free ammonia with increase of nitrates, but when the dilution of the Fox river is considered, it is plain that the change in albuminoid ammonia is not important. During the winter season the Fox river dilution was relatively greater, which lessens somewhat the apparent decrease in albuminoid ammonia at this time. It is true, however, that changes take place in this part of the river which in the warmer season took place above.

In the 28 miles between LaSalle and Henry no important changes have taken place.

At Peoria the river widens into a lake, which receives a por-

tion of the drainage of the city. The point where the samples were taken for analysis was evidently not beyond the influence of this contamination. During the winter this was increased by the drainage from sheds at the distilleries at which 25,000 head of cattle were fed. The effect of this is shown in the Peoria water, but most clearly in that from Pekin, ten miles below. Especially interesting is the great increase in nitrates observed at this point, and after the addition of *fresh* contamination.

Between Pekin and Beardstown there is a gradual improvement in the river, as shown by both summer and winter tests. Below Beardstown the Illinois was often diluted by back water from the Mississippi, which made the result of analysis irregular and obscure.

From the above it is apparent that while a gradual loss in organic matter occurs all the way between Bridgeport and Peoria, the rate of change was far less rapid in the summer of 1888 than in that of 1886. This difference, I believe, is chiefly due to differences in temperature and rainfall, which act directly and indirectly to modify the rapidity of bacterial oxidation.

In a wet summer the contents of the Chicago sewers, besides being cooled by rainfall, are rapidly washed out into the canal leading to the pumps. In a season of little rainfall much matter remains long enough in the sewers to become greatly modified by decomposition and consequently disappears rapidly when thrown into the main channel. These opposite conditions were illustrated in the summer seasons in which tests were carried out, and they doubtless can be duplicated in all large cities in which the sewers are built with but slight incline. Sedimentation cannot play a more important part in the apparent purification of these waters in summer than in winter. In fact, after the navigation of the canal closes in the early winter, precipitation can take place which was impossible during the warmer months. Yet the winter tests show practically no decrease in the organic matter between Bridgeport and Morris. It would appear, therefore, that the self-purification of a very cold water is a slow process, even when aided by sedimentation.

On the other hand, the very remarkable results obtained between Bridgeport and Joliet in our first season's work show that

with a sufficiently high temperature the disappearance of organic matter may be very rapid, unaided to any great extent by sedimentation.

It is known that temperature differences of a few degrees make very important differences in the rates of bacterial multiplication in many cases, and consequently in their efficiency as filth destroyers, and giving proper weight to this fact, I think many of the discrepancies observed between different examinations of the same polluted water, made at different times, may be explained.

The appearance and increase in nitrates and nitrites in the Illinois river affords us an instructive illustration. Frankland and others have shown that they are not formed in fresh sewage, and we see here that they appear only after a flow of many miles.

With the slower disappearance of albuminoid ammonia and less abundant formation of free ammonia in the cold season, we notice the later appearance of nitrates and nitrites. Investigation may show that the appearance of these compounds marks an important stage in the purification of a polluted stream.

It is probable that they are produced only after practically all the readily fermentable bodies have been more or less changed, as in presence of such matter denitrification can take place with destruction of nitrates, and evolution of nitrogen even. The greatly increased nitrates below Peoria after pollution by fresh drainage from the cattle sheds would seem to disprove this view. But such drainage is rich in hippuric acid, and this body, as well as its derivative, glycocoll, is readily broken up. Besides, because of the comparatively simple nature of the cattle feed (distillery slops and hay), the other matters present here must be less complex than what we have in ordinary city sewage, and therefore sooner converted into ammoniacal and other simple compounds.

Investigations, such as I have given an outline of above, are very difficult because of the practical impossibility of controlling all the conditions of experiments. Irregularities creep in where least expected, and in consequence the results of single observations have but little value when taken alone.

The results of investigations extended through a season have a different value, and I believe we can draw conclusions from these experiments on the Illinois which can be applied to the study of polluted river waters in general.

